

RL/REG-99-10
Revision 0

REVIEW OF BNFL DESIGN SAFETY FEATURES SUBMITTAL



April 12, 1999

Office of Radiological, Nuclear and Process
Safety Regulation of the TWRS-P Contractor

Richland Operations Office
P.O. Box 550
Richland, Washington 99352

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PREFACE

The Department of Energy's (DOE) Richland Operations Office (RL) issued a request for proposal in February 1996 for privatized processing of waste as part of the Hanford Tank Waste Remediation System (TWRS). Offerors were requested to submit proposals for the initial processing of the tank waste at the Hanford Site. Some of this radioactive waste has been stored in large underground storage tanks at the Site since 1944. Currently, approximately 54 million gallons of waste containing approximately 250,000 metric tons of processed chemicals and 215 million curies of radionuclides are being stored in 177 tanks. These caustic wastes are in the form of liquids, slurries, saltcakes, and sludges. The wastes stored in the tanks are defined as high-level radioactive waste (10 CFR Part 50, Appendix F) and hazardous waste (Resource Conservation and Recovery Act).

Under the privatization concept, DOE intends to purchase waste processing services from a contractor-owned, contractor-operated facility through a fixed-price contract. DOE will provide the waste feedstock to be processed but maintain ownership of the waste. The contractor must: a) provide private financing; b) design the equipment and facility; c) apply for and receive required permits and licenses; d) construct the facility and commission its operation; e) operate the facility to process tank waste according to DOE specifications; and f) deactivate the facility.

The TWRS Privatization Program is divided into two phases, Phase I and Phase II. Phase I is a proof-of-concept/commercial demonstration-scale effort the objectives of which are to a) demonstrate the technical and business viability of using privatized contractors to process Hanford tank waste; b) define and maintain adequate levels of radiological, nuclear, process, and occupational safety; c) maintain environmental protection and compliance; and d) substantially reduce life-cycle costs and time required to process the tank waste. The Phase I effort consists of three parts: Part A, Part B-1, and Part B-2.

Part A is a twenty-month period to establish technical, operational, regulatory, and financial elements necessary for privatized waste processing services at fixed-unit prices. This includes identification by the TWRS Privatization Contractors and approval by DOE of appropriate safety standards, formulation by the Contractors and approval by DOE of integrated safety management plans, and preparation by the Contractors and evaluation by DOE of initial safety assessments. Of the twenty-month period, sixteen months is for the Contractors to develop the Part-A deliverables and four months is for DOE to evaluate the deliverables and determine whether to authorize Contractors to perform Part B. Part A culminated in DOE's authorization on August 24, 1998, of BNFL Inc. to perform Part B.

Part B-1 is a twenty-four month period to a) further the waste processing system design introduced in Part A, b) revise the technical, operational, regulatory, and financial elements established in Part A, c) provide firm fixed-unit prices for the waste processing services, and d) achieve financial closure.

Part B-2 is a sixteen year period to complete design, construction, and permitting of the privatized facilities; provide waste processing services for representative tank wastes at firm fixed-unit prices; and deactivate the facilities. During Part B-2, approximately 10% of the total Hanford tank wastes will be processed.

Phase II will be a full-scale production effort. The objectives of Phase II are to implement the lessons learned from Phase I and to process all remaining tank waste into forms suitable for final disposal.

A key element of the TWRS Privatization Program is DOE's regulation of radiological, nuclear, and process safety through the establishment of a specifically defined regulatory approach and a specifically chartered, dedicated Regulatory Unit (RU) at RL. This regulation is authorized by DOE through the document entitled *Policy for Radiological, Nuclear, and Process Safety Regulation of TWRS Privatization Contractors* (referred to as the Policy) and is implemented through the document entitled *Memorandum of Agreement for the Execution of Radiological, Nuclear, and Process Safety Regulation of the TWRS Privatization Contractors* (referred to as the MOA). The Policy is signed by the Under Secretary of Energy; the Manager, RL; the Assistant Secretary for Environment, Safety and Health (ASEH); and the Assistant Secretary for Environmental Management (ASEM). The MOA is signed by the Manager, RL; the ASEH; and the ASEM. The MOA details certain interactions among RL, the ASEH, and the ASEM as well as their respective roles and responsibilities for implementation of the regulatory approach.

The authority of the RU to regulate the TWRS Privatization Contractor is derived solely from the terms of the TWRS Privatization Contract. Its authority to regulate the Contractor on behalf of DOE is derived from the Policy. The characteristics and scope of this special regulatory approach (special in the sense that it is based on terms of a contract rather than formally promulgated regulations) are delineated in the MOA, the TWRS Privatization Contract, and the following four documents, which are incorporated into the Contract and are part of the MOA.

Concept of the DOE Regulatory Process for Radiological, Nuclear, and Process Safety for TWRS Privatization Contractors, DOE/RL-96-0005

DOE Regulatory Process for Radiological, Nuclear, and Process Safety for TWRS Privatization Contractors, DOE/RL-96-0003

Top-Level Radiological, Nuclear, and Process Safety Standards and Principles for TWRS Privatization Contractors, DOE/RL-96-0006

Process for Establishing a Set of Radiological, Nuclear, and Process Safety Standards and Requirements for TWRS Privatization, DOE/RL-96-0004

Regulation by the RU in no way replaces any legally established external regulatory authority to regulate in accordance with their duly promulgated regulations nor relieves the Contractor from any obligations to comply with such regulations or to be subject to the enforcement practices contained therein.

In the execution of the regulatory approach through its regulatory program, DOE expects the RU to consider not only the relevant approaches and practices of DOE but also those of the Nuclear Regulatory Commission (NRC). The Policy states that

"It is DOE's policy that TWRS privatized contractor activities be regulated in a manner that assures adequate radiological, nuclear, and process safety by application of regulatory concepts and principles consistent with those of the Nuclear Regulatory Commission."

To this end, the RU interacts with the NRC (under the provisions of a memorandum of understanding with the NRC) during development of regulatory guidance and during execution of the regulatory program to ensure implementation of this policy.

All documents issued by the Office of Radiological, Nuclear, and Process Safety Regulation of TWRS-P Contractors are available to the public for review at DOE/RL Public Reading Room at the Washington State University, Tri-Cities Campus, 2770 University Dr., Richland, Washington. Copies may be purchased for a duplication fee.

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1.0 INTRODUCTION

The Contract¹ requires BNFL to submit to the Regulatory Unit (RU) for review and comment “a generic detailed description of the design safety features that will be incorporated into the waste treatment facility design.” The scope and content of the design safety features (DSF) Submittal are defined in the Agreement² between the Director of the RU and the General Manager of BNFL. BNFL provided this Submittal to the RU on February 24, 1999. Based on this Agreement, the RU was expected to review the Submittal and provide comments 45 days after its receipt (April 12, 1999).

2.0 SCOPE OF THE SUBMITTAL

The Agreement requires that BNFL provide two categories of information in the Submittal. The first category, Category 1, is a set of descriptions of the structures, systems, and components (SSCs) Important to Safety (ITS) and the associated DSFs planned for the facility. DSFs are defined in the Agreement as those aspects of an ITS SSC that ensure that it will perform its safety function. The second category, Category 2, consists of ten examples of BNFL’s detailed implementation of the Standards Identification Process,³ using BNFL’s Safety Requirements Document (SRD), Appendix A, “Implementing Standard for Safety Standards and Requirements Identification,”⁴ and Appendix B, “Implementing Standard for Defense in Depth.”⁵

3.0 REVIEW PROCESS

The purpose of the RU review of the DSF Submittal was to make an early assessment of BNFL’s approach to design safety. This preliminary assessment examined the set of ITS SSCs provided as Category 1 information in the DSF Submittal and the Standards Identification Process as implemented by BNFL in the ten examples included in Category 2 information.

The approach used in the assessment of the Submittal was for the reviewers to address a set of specific questions associated with each of the objectives listed in the Planning Handbook⁶ using the information in BNFL’s DSF Submittal.

4.0 REVIEW RESULTS

The results of the review of the DSF Submittal are described in the following sections. Section 4.1 summarizes the general findings of the Category 1 and Category 2 review.

¹ BNFL Contract No. DE-RP06-96RL13308, Section C, Standard 4, p. 58, August 1998.

² DOE Letter, 98-RU-0329, “Scope and Content for Design Safety Features Deliverable,” October 22, 1998.

³ *Process for Establishing a Set of Radiological, Nuclear, and Process Safety Standards and Requirements for TWRS Privatization* (Standards Identification Process), DOE/RL-96-0004, Rev. 1, 1999.

⁴ *Safety Requirements Document*, BNFL-5193-SRD-01, Appendix A, “Implementing Standard for Safety Standards and Requirements Identification,” Rev. 2, December 1998.

⁵ *Ibid.*, Appendix B, “Implementing Standard for Defense in Depth.”

⁶ *Planning Handbook for BNFL Inc. Design Safety Features Submittal Review*, RL/REG-99-08, Sections 7.2 and 7.3, February 1999.

Section 4.2 summarizes the results of the Category 1 review and Section 4.3 summarizes the results of the Category 2 review. Throughout the sections, specific references to reviewer comments are indicated in parentheses, and the actual reviewer comments are provided in the Appendix. The comments cited are examples only.

4.1 SUMMARY OBSERVATIONS

The DSF Submittal generally conformed to the expectations set forth in the Agreement on scope and content. While a number of concerns resulted from reviewing the Submittal, the RU reviewers concluded that BNFL demonstrated an adequate understanding of the Standards Identification Process and can effectively implement the Standards Identification Process to complete the design with adequate safety and defense in depth.

The information BNFL provided in Volume 1 (Category 1 information) of the Submittal was generally consistent with the scope specified in the Agreement, and the reviewers did not identify any significant concerns for Category 1 that must be resolved before the Construction Authorization Request (CAR) is submitted. The RU reviewers conclude that the set of generic ITS SSCs and DSFs can provide an adequate range of controls to address the TWRS-P hazards. The set of SSCs and DSFs reflects BNFL's experience in controlling hazards in comparable waste processing activities. Because of the early stage of design and the generic nature of Category 1 information provided, the RU reviewers could not draw definitive conclusions on BNFL's approach to safety or defense in depth. However, several examples of inconsistencies between the Safety Requirements Document and the DSF Submittal were identified, as well as other omissions and inconsistencies in identifying ITS SSCs.

Information provided in Volume 2 (Category 2) of the Submittal was also generally consistent with the scope and content specified in the Agreement. Based on the review of Category 2 information, the RU reviewers concluded that BNFL has satisfactorily implemented all but one of the steps of the Standards Identification Process. The one step inadequately implemented concerns the justification of selected standards. In all but one of the ten examples included in Category 2, such justification was very weak or absent altogether (see Section 4.3.2.1 below). The reviewers also identified a number of other concerns that primarily involve the methodology used in the hazard analysis: treatment of uncertainties; treatment of unmitigated events analysis; validity of the source-term calculations; application of passive, nonredundant SSCs; fire protection approach; chemical hazards approach; and validity of Sellafield data.

The acceptability of the Category 2 information in the Submittal should not be construed as "approval" of the control strategies or the associated SSCs. The Agreement calls for descriptions and justifications of Design Basis Events (DBEs). However, prior to the DSF Submittal, the RU and BNFL agreed that lack of design maturity precluded selection of DBEs in the Submittal. Instead, the RU and BNFL agreed that BNFL would select ten examples, encompassing a range of consequences and frequencies of occurrence, to demonstrate the Standards Identification Process. However, it should be recognized that the lack of consideration of DBEs can lead to an incomplete evaluation of the control strategies and definition of the ITS SSCs.

4.2 RESULTS OF CATEGORY 1 REVIEW

The results of the Category 1 review are first summarized and then described in more detail in the following subsections.

4.2.1 General Observations

Given the preliminary status of design reflected in the Category 1 information, the DSF Submittal delineation of ITS SSCs and related DSFs is acceptable. The Submittal information described a “tool box” of generic SSCs and DSFs with which BNFL has considerable experience in applications that are comparable to the envisioned TWRS-P applications.

While the level of design maturity reflected in the Submittal did not permit definitive conclusions regarding the adequacy of the set of SSCs identified, the reviewers did not find any significant concerns that require resolution before the CAR is reviewed. However, several comments were made regarding the inadequate detail in the information. These include instances in which the material is potentially in conflict with the SRD or in which several classes of potential ITS SSCs are either omitted or are not adequately described.

4.2.2 Specific Comments

The following are general and specific comments from the Category 1 review:

1. **Inconsistency with the SRD** – In some cases, the information was potentially in conflict with the safety criteria and implementing standards in the SRD. Examples include the following:
 - Design of the wet chemical storage facility to the Uniform Building Code was inconsistent with BNFL commitments (M-05).
 - Design of the instrument air system was inconsistent with BNFL commitments (M-13).
 - Fire protection system description was inconsistent with BNFL commitments (M-27).
 - Cold chemical feed systems may need to be designated ITS (B-01).
2. **Incomplete listing of ITS SSCs** – Several potentially significant hazards were not considered and some ITS SSCs that are known or expected⁷ were not identified in the Category 1 material. Examples include the following:
 - The DSFs and SSCs for nitric acid handling were inconsistent with those from Category 2 (M-18).

⁷ *Planning Handbook for BNFL Inc. Design Safety Features Submittal Review*, RL/REG-99-08, Rev. 1, Section 7.4.1.1, “Expected Category 1 Information,” February 23, 1999.

- There is no discussion of leakage into and contamination of secondary heat exchange systems (M-14).
 - Cross contamination among vessels leaking through primary cooling systems is not discussed (M-15).
 - The hazardous conditions of evaporator collapse, steam leaks, and tube leaks in evaporator systems are not included (M-21).
 - Non-uniform mixing from pulse-jet (fluidic) agitators may lead to criticality hazard (M-23).
 - Steam explosions or pressure transients due to aqueous slurry feed to melters are prematurely dismissed (E-01, B-02).
 - ITS SSCs and DSFs for Tank 241-AP-106 are not presented (G-04).
 - ITS SSCs and DSFs for managing entrained solids product are not presented (G-05).
3. **Inadequate description of SSCs and DSFs** – The DSFs and safety functions of some ITS SSCs were not identified. Examples include the following:
- A description of interlock DSFs is not presented (M-25).
 - Description of high-level waste receipt and pretreatment is insufficient to understand operation of the system (see Section 2.8.5 and Figure 2.8-6) (M-29).
 - The roles of cell and cave structures and associated DSFs in achieving secondary confinement are not addressed (A-01).
4. **Insufficient information for review** – In several cases, insufficient information was provided for review. Examples include the following:
- The specific relevance of safety management practices used at Sellafield, including terms such as “safety case,” “safety mechanism,” “safety related equipment,” and “operational clearance certificates,” was not explained (M-07).
 - The discussion of reverse flow diverters was too limited to understand how these components function or their failure modes (M-19).
 - Some terminology was not explained, such as “tundish,” “active sump arisings,” “freeze valves,” “lutes,” “diode pumps,” and “breakpots” (M-20).
 - Five vessel design groups were said to exist, but only the characteristics of the highest integrity (Group 1) vessels were identified (B-06).

- The pump transfer flask was not described, e.g., materials of construction, environmental conditions, fabrication technology, and metallurgical condition (B-05).

4.3 RESULTS OF CATEGORY 2 REVIEW

The results of the Category 2 review are first summarized and then significant general concerns and significant specific concerns are described in more detail below.

4.3.1 General Observations

The review of the Category 2 information indicated that BNFL satisfactorily implemented all but one step—justification of the selected standards—in the Standards Identification Process. While several significant concerns were identified, most pertained to the details of analyses supporting the hazard assessment in the ten specific examples.

4.3.2 Significant Concerns

The following sections describe significant concerns resulting from the review of Category 2 information.

4.3.2.1 Justification of Standards Selection

The justification of standards for the ten Category 2 examples was generally weak or nonexistent, with one exception—Section 3.9. This section developed the control strategy to prevent activity backflow from a process vessel into the vessel wash cabinet. In the Submittal, five design standards were specified in Section 3.9.4.5, “Design Standards,” to implement the control strategy. Each standard was cited with a brief statement of what the standard does. A justification of the selected design codes and standards for the other nine Category 2 examples generally was not provided. This key aspect of implementing the Standards Identification Process should be more fully addressed in the CAR.

The “Implementing Standard for Safety Standards and Requirements Identification”⁸ states the following:

“Documentation of the standards and requirements identification process provides justification of the set selected and links each control strategy to its associated set of standards. The information generated during standards selection is retained in database form for each control strategy (and includes)...standards justification.”

Although Section 3.9 of the Submittal is clearer than the other nine examples in this regard, it also does not clearly state the basis for the selection of each standard. Section 3.9 noted the presence of cells, wash cabinets, and wash rings, but the relevance of the Code of Practice for

⁸ *Safety Requirements Document*, BNFL-5193-SRD-01, Rev. 2, Appendix A, “Implementing Standard for Safety Standards and Requirements Identification,” Section 6.0 “Identification of Standards,” December 1998.

shielded and unshielded glove boxes was not clear. Glove boxes are not explicitly required for the proposed design solution. It is possible that the Code of Practice for shielded and unshielded glove boxes contributes valuable guidance to formulating the detailed design solution for the example analyzed in Section 3.9 of the Submittal. However, this was not clear from the information provided.

4.3.2.2 Treatment of Assumptions and Uncertainties in Modeling and Data

Uncertainties associated with both unmitigated and mitigated accident consequences and frequencies generally⁹ were not described, evaluated, and accounted for in the Category 2 examples. The DSF Submittal states, in Section 3.0.1 (page 5):

“Uncertainties in the design and accident consequence analysis that, upon resolution, may result in challenging the radiological exposures standards, have been accommodated by selecting preferred control strategies (including SSCs and DSFs) that result in estimated exposures to the facility workers, co-located workers, and the public that are significantly below the radiological exposure standards. This is apparent by review of the Section 3.x.5.3, “Mitigated Consequences” for the radiological examples presented.”

Despite this assertion, BNFL is expected to justify or clarify all assumptions, models, and data used in the accident analysis. The Contract¹⁰ requires this presentation of assumptions and uncertainty in models and data. The need to clarify these assumptions and uncertainties for DBEs will be especially important in the CAR. DSF Category 2 examples that raise potentially important questions about assumptions and uncertainties in models and data include the following:

- hydrogen generation in the HLW receipt tanks (rate of hydrogen generation) (H-11)
- cooling water contamination (e.g., initiating event frequency and coil failure frequency) (Q-16)
- low-activity waste pipe break (concentration of waste entrained in air above pool) (J-06)
- receipt vessel rupture (aerosol concentration assumption) (K-04)
- nitric acid handling (exposure limit distance) (H-15).

From the DSF Submittal, it was not apparent whether adequate margin had been used in selecting control strategies. BNFL may choose to reflect uncertainties in the CAR through a qualitative expression of ranges of frequency and consequence. While justification of these selected ranges is expected, a Probabilistic Risk Analysis is not required or expected.

⁹ Exceptions include Section 3.3.2.4, where uncertainty in frequency of load drop is estimated, and Section 3.7.3.2, where uncertainty in the size of a leak that could be detected is mentioned but not quantified.

¹⁰ *DOE Regulatory Process for Radiological, Nuclear, and Process Safety for TWRS Privatization Contractors*, DOE/RL-96-0003, Rev. 1, 1999, Section 4.3.2, Item 15, “Contractor Input,” Authorization for Construction, which states: “An analysis of the safety basis for the facility, in terms of assumptions made, uncertainties in data and analyses...”

Justification can be accomplished by carefully examining and expressing all assumptions and uncertainties in models and data.

4.3.2.3 Evaluation of Unmitigated Events

The methodology for conducting unmitigated evaluations did not consistently meet existing SRD requirements regarding such evaluations. BNFL must correct this deficiency before the CAR is submitted.

In evaluating the unmitigated dose consequences in several examples in Category 2, BNFL has taken credit for dose mitigation provided by some of the facility's passive design features. For example, in the Submittal BNFL took credit for a decontamination factor (DF) of 10 to 100 based on plate-out or other mechanisms for mitigation in evaluating the "unmitigated" dose consequences from "Loss of Cooling to the Cesium Storage Vessel" (Section 3.2), "High Level Melter Feed Line Failure" (Section 3.4), and "Receipt Vessel Rupture" (Section 3.8) events. This approach is inconsistent with Appendix A of the SRD, which states that an unmitigated event involves "failure of all elements of the control strategy that would mitigate the consequences of the release."

The RU recognizes that the BNFL approach in these examples may be defensible under certain circumstances, but in the Submittal BNFL had not clearly addressed these circumstances. For example, if the ventilation ducts are assumed to provide a certain amount of plate-out, the design features necessary to provide such performance must be designated as design requirements or ITS SSCs. The Submittal did not clearly indicate that this was the case. Physical structures, because of low probability of failure, can in some cases be assumed to retain general physical integrity unless they are damaged by the initiating event. However, specific performance features of physical structures are not necessarily assured. For example, leak tightness of cells after an event cannot be assumed (in an unmitigated event analysis) unless its loss is justified to be incredible. Otherwise, leak tightness of the cell should be designated as part of the required control strategy with established performance and reliability requirements. The unmitigated event needs to be evaluated in this manner to establish the performance and reliability requirement on the leak tightness of the cell.

4.3.2.4 Evaluation of the Source Term

Several of BNFL's source-term assumptions departed from its established Accident Analysis Code of Practice¹¹ without adequate justification.

To support the accident analysis associated with the DSF Submittal, BNFL calculated radiation doses to co-located workers and the public using various methods to estimate the source term. The source term is defined for this discussion as the amount of radioactive material made airborne and released from the facility as a result of each specific event considered. BNFL's *Code of Practice for the Accident Analysis Process* provides a framework that could enable a consistent approach to be applied when undertaking accident analysis.

¹¹ *Code of Practice for the Accident Analysis Process*, K70C505_0, BNFL, December 1998.

Specific to the source term, the Code of Practice defines the approach the analyst should take, stating: “Where a range of possible initial conditions, physical properties, or environmental conditions exists, the range should be specified, and the *most conservative physically credible combination of conditions* (emphasis added) chosen.”¹² As part of the DSF review, three concerns have been identified regarding the accident analysis:

1. **Applying the 10 mg/m³ value to one volume of cell space air as a source-term method** – As an alternative to the established methods described in the BNFL’s Code of Practice, BNFL assumed that the postulated accident produced a constant, average stable airborne concentration of respirable material of 10 mg/m³ over a selected volume of air (i.e., one volume of the cell air space). The reference cited was Sutter,¹³ which further referenced a report from Oak Ridge National Laboratory (ORNL).¹⁴ Although this approach could be used to estimate the source term, BNFL did not adequately describe the approach. BNFL did not compare the results with those produced using the methods described in its Code of Practice, did not ensure it had performed the calculations in a manner consistent with the intent of the data, and did not adequately justify key assumptions (i.e., the assumed one volume of the cell air space).
2. **Assigning decontamination factors (DFs) in a bounding analysis** – In its bounding analysis of postulated accidents, BNFL included DFs to further reduce the quantity of radioactive material released from the facility. These DFs may be acceptable for some methods if a reasonable justification can be made that, even with their inclusion, a bounding analysis will result. The referenced ORNL report indicates that the 10 mg/m³ represents the stable airborne concentration in an off gas line after the concentration has been reduced by the ventilation system configuration. The use of the 10 mg/m³ value and the DF of 10 for the removal of airborne material by the ventilation system in the same analysis does not appear appropriate or justified.
3. **Using nonbounding assumptions for the material at risk** – To estimate the material at risk, the DSF Submittal considered the published Best Basis Inventory for Tank 241-AZ-101.¹⁵ The analysis states that this tank has the highest concentration of americium-241 and strontium-90, which are the principal radionuclides contributing to inhalation dose. When compared with the maximum radionuclide composition reported in the BNFL Part B-1 Contract for HLW Envelope D using BNFL process assumptions regarding the presence of 25% by weight of solids, the BNFL source term was determined by the reviewers to be a factor of 3.7 lower than that for the contract-based maximum radionuclide concentration.

¹² Ibid., Section 5.5, p. 9.

¹³ *Accident Generated Particulate Materials and Their Characteristics – A Review of Background Information*. NUREG/CR-2651, U.S. Nuclear Regulatory Commission, Washington, D.C., 1992.

¹⁴ *Siting of Fuel Reprocessing Plants and Waste Management Facilities*, ORNL-4451, Oak Ridge National Laboratory, Oak Ridge, Tennessee, July 1970.

¹⁵ *Evaluation to Establish the Best-Basis Inventory for Double-Shell Tank 241-AZ-101*, WHC-SD-WM-ER-A10, Appendix D, Rev. 0B, Westinghouse Hanford Company, Richland, Washington.

4.3.2.5 Use of Passive, Nonredundant SSCs

The DSF Submittal credits some passive, nonredundant SSCs as sufficient to achieve adequate safety for Severity Level 1 and 2 hazards. However, the DSF Submittal does not contain sufficient information to conclude that these SSCs will be highly reliable. Safety Criterion 4.1-2 of the SRD requires SSCs, to the maximum extent practical, to have design features that “enhance the margin of safety through simplified, inherently safe, passive, or other highly reliable means to accomplish the specified safety function.” Thus, while passive design features are encouraged, they must be highly reliable and practical in order to be acceptable. Examples of “passive” SSCs proposed by BNFL include the following:

- passive post-accident ventilation of the high level waste receipt tanks to remove hydrogen (H-08)
- passive post-accident cooling for tanks (K-09)
- passive post-accident confinement of radioactive or hazardous chemical material within caves and cells (A-01).

Unlike a shield wall, which passively provides shielding with high reliability, the demonstration of high reliability for the example SSCs poses demanding analytic and experimental engineering challenges. These issues are likely to be problematic when the CAR is reviewed. For example, in the Category 2 example of hydrogen generation in high level waste storage vessels (Section 3.1 in the Submittal), BNFL identified many open issues. These open issues detail some of the factors that will complicate the technical analysis required to satisfactorily demonstrate acceptable functional performance of the passive ventilation systems for reliably maintaining hydrogen concentrations at safe, low levels in the vessel and in the cell.

An additional complicating factor is apparent in Submittal Figure 3.1-2, “Control Strategy Schematic,” which shows three vessels (all presumably generating hydrogen by radiolysis but no doubt at different, variable rates depending on particular tank inventories and compositions) tied together to a common active ventilation duct. The active ventilation system must maintain suitably balanced flows through all vessel headspaces tied to the common ventilation header if vessel hydrogen concentrations are to be maintained at safe levels. The common ventilation header shared by a group of vessels may, however, present an additional difficulty in maintaining adequate, *passive* ventilation flows through each of the vessels whenever active ventilation is lost. This is because the common ventilation header will likely behave as a cross-connection between the contiguous vessels and permit tank atmospheres to migrate from tank to tank depending on buoyancy (a function of hydrogen concentrations and tank temperatures).

Similarly, in the example involving decay heat analyzed in Section 3.2, “Loss of Cooling to the Cesium Storage Vessel,” in the Submittal, the cesium storage vessel and cell are proposed to be sized to transfer decay heat at rates sufficient to prevent the solution from boiling and releasing a radioactive aerosol. The possible release of volatile technetium compounds from the hot solution, although not discussed in the Submittal, may be a complicating factor. The maximum allowable temperature for the solution may need to be less than the boiling point of the solution. Section 3.2.4.2.1 in the Submittal states that the size of the vessel to passively reject the decay heat will be resolved in future design. Although the vessel will be provided with two internal

cooling coils with forced circulation of coolant, an attempt will be made to provide sufficient vessel surface area so that the decay heat can be removed by radiative and convective heat transfer without approaching the solution boiling point. The inside and outside heat transfer coefficients will be key parameters controlling success or failure for the passive cooling design approach, which relies on natural convection of the cesium-laden solution and on cell air to transfer heat out of the vessel. Furthermore, the cell will presumably have to transfer the heat away without reliance on forced ventilation if the cooling system is to be completely passive in design.

The RU will require clear analytic and experimental demonstration of the efficacy of such novel engineering solutions for control strategies. BNFL should reach early agreement with the RU in these areas to minimize risk of major redesign later. Timely approval of the CAR depends on convincing prior demonstration of the high reliability of these passive SSCs.

4.3.2.6 Fire Protection

The DSF Submittal does not adequately reflect BNFL's commitments¹⁶ to the fire protection system design, Fire Hazards Analysis, and fire protection program. The DSF Submittal states:

- “[The fire water tank and pump house] is a light weight steel structure with rated fire wall to protect the fire protection equipment from inclement weather . . .” (Section 1.4.11)
- Regarding the design safety features of the automatic suppression systems, “the safety analysis will demonstrate that there will be no impact on safety should the fire not be extinguished.” (Table 2.9-1)
- Regarding the design safety features of the fire detection and alarm systems, “the safety analysis will demonstrate that there will be no impact on safety should the fire not be detected.” (Table 2.9-1)

The cited text indicates that BNFL considers there will be no credible fires with an “impact on safety,” and thus no need for fire detection and alarm systems, automatic suppression systems, or protection against natural phenomena hazards. This is inconsistent with Table 2.9-1, which shows that much of the fire protection systems will be ITS. The judgment that there are no credible fires with an “impact on safety” is premature, given the facility's large size and various hazardous energy sources. BNFL should resolve this concern before the CAR is submitted.

4.3.2.7 Chemical Hazards

BNFL's hazard evaluation for the nitric acid handling example (Section 3.10 in the Submittal) did not include an estimate of the frequency of this chemical accident. Section 4.9 of Appendix A of the SRD requires BNFL to document the frequency of accident sequences. No specific exemption is made for chemical hazards and associated accidents. BNFL also stated in the Submittal (Section 2.5.7.3; also see comment B-01) that the cold chemical feed system is not

¹⁶ The commitments were made during the Fire Protection Topical Meeting, February 23, 1999.

considered to be ITS and the handling equipment will be designed using accepted chemical industry codes and standards. However, this is inconsistent with SRD Safety Criterion 1.0-8. The nitric acid handling accident exceeded ERPG-2 equivalent limits for exposure to workers and co-located workers. Therefore, this event would require the design to include ITS SSCs.

At the March 23, 1999, DSF Topical Meeting, BNFL informally proposed changing the SRD to remove the requirement for chemical facilities to be designed to PC-3 if a natural phenomena hazard can lead to an ERPG-2 exposure. BNFL would need to demonstrate that BNFL's proposal complies with the radiological, nuclear, and process safety objectives of the Top-Level Standards.¹⁷

BNFL should resolve these concerns before the CAR is submitted.

4.3.2.8 Use of Sellafield Practices and Data

The applicability of BNFL Sellafield practices (control strategies, data bases, standards, and administrative procedures) proposed for use in TWRS-P will require detailed justification (see comments M-07 and O-07).

4.3.3 Significant Specific Concerns

The following section describes some significant concerns that were identified from the review and that apply to specific Category 2 examples.

4.3.3.1 Tailoring of National Fire Protection Association (NFPA) 69

As an outcome of the hydrogen generation example (Section 3.1 in the Submittal), BNFL selected NFPA 69 as one of the standards in a set for attaining the target reliability for the active vessel ventilation system. BNFL stated in the submittal that NFPA 69 did not apply to control of hydrogen associated with radiolysis in HLW storage vessels. In adopting it for this situation, BNFL chose to tailor its application. BNFL's tailoring and application of NFPA 69 for the example on hydrogen generation and the passive ventilation system (Section 3.1 in the Submittal) are concerns that should be resolved before the CAR is submitted (see comment H-01).

In the Submittal, BNFL's proposed tailoring of NFPA 69 was not properly done. Apparently, BNFL misunderstood the scope and content of NFPA 69. In the March 23, 1999, DSF Topical Meeting, BNFL recognized that its proposed justification for the tailoring in the DSF Submittal was incorrect; however, BNFL stated that it does not wish to use NFPA 69 as a standard applicable to designing the passive ventilation system. Instead, BNFL has proposed using a hydrogen concentration limit of 4% [100% of lower flammability limit (LFL)] as the applicable design criterion for the passive ventilation system. Furthermore, BNFL does not propose to

¹⁷ *Top-Level Radiological, Nuclear, and Process Safety Standards and Principles for TWRS Privatization Contractors* (Top-Level Standards), DOE/RL-96-0006, Rev. 1, 1999.

provide any continuous hydrogen monitoring or any provisions for automatic corrective actions when hydrogen concentration approaches unsafe levels.

The RU reviewers had significant concerns with this design approach given the many uncertainties associated with the hydrogen generation rate and ventilation flow rate under passive operation. While the active ventilation system may maintain hydrogen concentrations virtually below detectable limits, that degree of hydrogen control seems unlikely for the passive ventilation system.

4.3.3.2 Defense in Depth Exception for Load Drop of Pretreatment Pump

Section 3.3, “Load Drop of Pretreatment Pump,” in the DSF Submittal proposes a single physical barrier against the release of radioactivity (the flask) and an exception to the Implementing Standard for Defense in Depth¹⁸ using the argument that “the analysis shows that the control strategy meets the consequence and frequency targets with margin.” This statement is not adequately justified considering the number of concerns identified in this report (see comment K-03 and Section 3.3.6, “Conclusions and Open Issues” in the Submittal).

A more thorough examination of alternative strategies should be pursued before such an exception is sought. This should include more extensive examination of alternatives such as considering the use of a wheeled flask for the transfer, pre-evacuation of the route, and examination of collateral damage associated with crane accidents.

BNFL’s consideration of these alternatives and a justification of the exception to the Defense in Depth Implementing Standard should be completed and discussed with the RU before the CAR is submitted.

4.3.3.3 Initiating Event Frequencies for LAW Pipe Break

Section 3.7, “Low Activity Waste Pipe Break,” in the Submittal provided the unmitigated frequency estimate for a guillotine break of the primary and secondary pipes of a low-activity waste transfer line as a result of an inadvertent excavation using mechanical digging equipment. As noted in comment J9, BNFL has misinterpreted a Westinghouse Hanford Company engineering study of the stress on primary and secondary piping due to loads imposed by the wheels of backhoes by assuming that the loads were imposed by the excavating bucket/grab rather than by the wheels. The misinterpretation affects the estimate of the frequency of pipe break and should be corrected in the CAR.

4.3.3.4 Justification of Control Strategy for Receipt Vessel Rupture

The strategy used for identifying and evaluating potential control strategies for “Receipt Vessel Rupture,” Section 3.8 in the Submittal, did not follow the process defined in BNFL’s

¹⁸ *Safety Requirements Document*, BNFL-5193-SRD-01, Appendix B, “Implementing Standard for Defense in Depth,” Rev. 2, December 1998.

Appendix A of the SRD. Instead, the following is included in the first paragraph of Section 3.8.3.1 in the Submittal: “The consideration of multiple alternative control strategies for this hazard has not been carried out since a mature, proven strategy already exists within BNFL for the handling and storage of radioactive liquors. ... The control strategy consists of primary (vessel) and secondary (cell) confinement and a C5 filtered extract ventilation system.”

This response is inadequate compared with Section 5.0 of BNFL’s Implementing Standard (Appendix A of the SRD), which requires the selection of a preferred control strategy from a set of potential controls and the documentation of all control strategies considered. Also, as stated on page 4 of the DSF Agreement on scope and content, even when a mature control strategy exists, information should be provided, to the extent that such information exists, on the alternatives to control the hazard and the use of the control strategy selected, based on operational experience. The RU expects BNFL to follow the Implementing Standard in development of controls for the hazards associated with their facility and in documenting those controls in the CAR.

4.3.3.5 Description of Control Strategy for Activity Backflow

The activity backflow example (Section 3.9 in the Submittal) introduces the concept of a “composite” control strategy in addition to the preferred strategy. This terminology appears to be used by BNFL in generalizing the preferred strategy such that it applies to the broader class of activity backflow situations involving airborne activity and many different vessels. Accordingly, the composite control strategy includes active SSCs; however, the selected control strategy is limited to two passive engineered safety features. This generalization causes confusion in the selection and description of the control strategy.

The activity backflow example provides an assessment of the selected control strategy for satisfying the Top-Level Principles. While the assessment is thorough, the control strategy assessed is the composite (generalized) strategy rather than the preferred control strategy. Specifically, the assessment largely ignores the non-immersed wash ring element of the selected control strategy and instead refers to 3-way vent valves, loop seals, radiological monitoring, and/or the cascade properties of the facility ventilation system design as elements of the selected control strategy. In this example, BNFL fails to consistently identify and evaluate a single preferred control strategy, thereby adding confusion to the control strategy development process and adding ambiguity to the RU’s review of its adequacy.

To support an efficient and successful RU review of the CAR, BNFL should ensure clarity and consistency in its development, assessment, and documentation of control strategies.

5.0 FOLLOW-UP ACTIONS

Several follow-up actions should be taken prior to the CAR to resolve concerns identified in this report:

1. **Standards justification** – BNFL should develop an acceptable approach to justification of standards in the context of the Standards Identification Process. See Section 4.3.2.1 of this report.
2. **Treatment of chemical hazards** – BNFL should develop an acceptable approach to a treatment of chemical hazards that is consistent with the treatment of radiological hazards, as required by the Contract. See Section 4.2.2, item 1, and Section 4.3.2.7 of this report.
3. **Unmitigated event analysis** – BNFL should develop an acceptable approach to unmitigated event analysis. The following items should be addressed:
 - definition of “unmitigated” consequence analysis and use of decontamination factors (see Section 4.3.2.3 of this report)
 - determination of bounding source terms (see Section 4.3.2.4 of this report)
 - determination of uncertainty ranges for initiating frequency and consequences (see Section 4.3.2.2 of this report)
 - justification of data, assumptions, and models (see Section 4.3.2.8 of this report).
4. **Approval basis for passive systems** – BNFL should develop an acceptable analytical and experimental program for validating passive approaches for hydrogen ventilation from vessels and cells, for passive cooling of vessels, and for passive confinement in cells. Achieving appropriate flammability and temperature limits and functional reliability should be addressed. (See Sections 4.3.2.5 and 4.3.3.1 of this report.)

The RU will schedule topical meetings to discuss BNFL’s corrective actions on these topics, on a mutually agreeable schedule.

APPENDIX – DETAILED REVIEWER COMMENTS

This appendix provides detailed RU reviewer comments generated during review of the DSF Submittal. Each comment referred to parenthetically in the report is provided as well as other comments not referenced in the report. The nonreferenced comments are of varying importance and are provided for BNFL’s consideration as appropriate. The comments are in alphabetical order according to comment number. Each comment form shows whether the comment relates to either the Category 1 or Category 2 portion of the Submittal and identifies the comment “Type” (A, B, C, or D), as referenced in the DSF *Planning Handbook*.

Table 1 shows how each comment relates to individual DSF review report sections. The column entitled “Other” identifies comments that are not referenced in the report and that are related to inadequate documentation (Doc), to technical issues (Tech), or to miscellaneous (Misc) other topics. The highlighted comments are referenced in the body of the DSF Review Report.